Powers of Ten
Number Sense and Scientific Notation

How big is the solar system? our galaxy? the universe? In our everyday experience it is difficult to fathom such great distances. Large sizes and distances mean large numbers which we often write in scientific notation. This activity is designed to help you understand relative sizes in the universe and scientific notation. Complete the introductory activity before watching the video clip.

Introductory Activity

1. Write the number 10^4 (same as 1×10^4) in decimal form - 10,000
2. Write the number 25,000,000 in scientific notation - 2.5×10^7
3. Write the number 5×10^{-3} in decimal form – .005
4. Write the number 0.000001 in scientific notation - 1×10^{-6} or 10^{-6}
5. The number 10^8 is how many times bigger than the number 10^3? $10^8 \div 10^3 = 10^5$
6. What would you estimate to be your height in meters? (std answer)
7. What would you estimate to be the length of your classroom (m)? (std answer)
8. Measure your height and the length of your classroom and compare your answers with your estimates in the previous two questions. What did you find?

   (std answer)

9. Order the following objects from smallest to largest: ~~planet~~, galaxy, ~~sun~~, ~~solar~~ ~~system~~, ~~universe~~, ~~Hercules star cluster~~, ~~Virgo cluster of~~ galaxies.

   ~~planet, sun, solar system, Hercules star cluster, Virgo cluster, universe~~

10. What would you estimate to be the diameter of the earth?
    a) 10^2 m b) 10^5 m c) 10^7 m d) 10^{12} m e) 10^{18} m
11. What would you estimate to be the size of the moon's orbit?
    a) 10^5 m b) 10^8 m c) 10^{12} m d) 10^{20} m e) 10^{32} m
12. What would you estimate to be the size of our solar system?
    a) 10^7 m b) 10^{10} m c) 10^{13} m d) 10^{18} m e) 10^{25} m
13. What would you estimate to be the size of our galaxy?
    a) 10^6 m b) 10^9 m c) 10^{14} m d) 10^{21} m e) 10^{46} m

(std answ

Video Activity – Part 1

The first part of the video you are about to watch starts with a couple having a picnic near Lake Michigan in Chicago. Every 10 seconds, you will view this picnic from 10x farther away and the size of the image will be 10x larger. While watching the video you will see numbers appear on the left and right side of the image identifying the distance from the picnic site and the size of the image (distance and image size are the same in this video). While watching the video clip, record the answers for each of the following statements.

a. 100 m = distance a man can run in __10__ seconds

b. __1__ km = distance a race car can travel in 10 seconds

c. 10 km = distance a __supersonic airplane__ can travel in 10 seconds

d. 10^5 m = distance an orbiting satellite travels in __10__ seconds

e. The diameter of the earth is approximately __10^7__ meters

f. The moon orbits between __10^8__ m and __10^9__ m away from the earth.

g. Jupiter orbits about how far from the earth? __10^{12}__

h. The outer reaches of the solar system (Pluto's orbit) is how far from earth? __10^{13}__

i. Approximately how wide is the solar system? __10^{13} m__

j. A light-years is equivalent to __10^{16}__ meters. $= 9.46 \times 10^{15}$ m

k. The star, Arcturus, is about __$\sim 10^{18}$__ meters from earth.

l. Our galaxy is approximately how wide in meters? __10^{21}__ in light-years? __100,000__

m. The Virgo cluster of galaxies is approximately how far from earth in meters? __10^{24}__ in light-years? __100 million ly__

Post-Lab Questions

1. Revisit your answer to question #9 in the Introductory Activity. Discuss any changes you might make now that you have viewed the video.

(std answer)

2. Compare your estimates from questions #10-13 in the Introductory Activity section with your answers from the video. Comment on how close you were to being correct. Did you, in general, overestimate or underestimate?

(std answer)

Use your data from the video to calculate the following:

3. Our solar system is how much larger than the earth?

$10^{13}\ m / 10^{7} = 10^{6}\ x$ (1 million times)

4. Our galaxy is how much larger than the earth? than the solar system?

$10^{21} / 10^{7} = 10^{14}\ x$

5. If one mile is equivalent to 1609 meters,
   a. how wide is our solar system in miles?

$1 \times 10^{13}\ \text{meters} \times \frac{1\ mi}{1609\ m} = 6.2 \times 10^{9}\ \text{miles}$

(6.2 billion miles)

   b. how wide is our galaxy in miles?

$1 \times 10^{21}\ m \times \frac{1\ mi}{1609\ m} = 6.2 \times 10^{17}\ \text{miles}$

6. A light-year is the distance light will travel in one year. You were provided the length of a light-year during the video. If light travels through space at 3.0×10^{8} m/s, calculate how long it would take for light to travel $1\ l_y = 10^{16}\ m$
   a. from earth to Jupiter?

Jupiter is $\approx 10^{12}$ m from earth

$10^{12}\ m \times \frac{1\ s}{(3 \times 10^{8}\ m)} \approx 3300\ s$

≈ 0.9 hours

   b. across our solar system?

$10^{13}\ m \times \frac{1\ s}{(3 \times 10^{8}\ m)} = 3.3 \times 10^{4}\ s$

≈ 9 hours

   c. across our galaxy?

$10^{21}\ m \times \frac{1\ s}{(3 \times 10^{8}\ m)} = 3.3 \times 10^{12}\ s$

$\approx 9 \times 10^{8}$ hours $\approx 3.9 \times 10^{7}$ days $\approx 106{,}000$ years

   d. from the star, Arcturus?

$10^{18}\ m \times \frac{1\ s}{(3 \times 10^{8}\ m)} \approx 3.3 \times 10^{9}\ s \approx 106$ years

"time travelling when viewing stars!"

7. Based on your calculations from question #4 and 6c, comment on why detecting other forms of intelligent life (if it exists) in our galaxy and the universe is so difficult.

Takes a very long time for communication to travel just within our solar system let alone our galaxy.

8. Everything moves within the solar system, within our galaxy and within our universe. Let's assume the motions described below are circular meaning the object is moving along the circumference of a circle. If the equations for the circumference of a circle are C = 2 x pi x r or C = pi x d, how fast are the objects described below actually moving? (speed = distance / time)
   a. person rotating on equator of earth (radius of Earth at equator = 3964 miles)

$$V = \frac{2\pi r}{t} = \frac{2\pi(3964\,mi)}{24\,hr} = 1{,}038\,mph$$

   b. earth around the Sun (average Earth-Sun distance = 93 million miles)

$$V = \frac{2\pi\,(93\times10^{6}\,miles)}{1\,yr \times \frac{365\,d}{yr} \times \frac{24\,h}{d}} = 66{,}705\,mph$$

   c. Sun around center of Milky Way Galaxy assuming it takes 240 million years for the sun to complete one revolution around the galactic center (average distance of Sun from center of galaxy = 26,000 light-years)

$$V = \frac{2\pi\left(26{,}000\,ly \times 10^{16}\,m/ly \times \frac{1\,mi}{1609\,m}\right)}{240\times10^{6}\,yrs \times \frac{365\,d}{yr} \times \frac{24\,h}{d}} = \sim 483{,}000\,mph$$

Websites based on the video concept of Powers of Ten:

1. Cosmic View (precedes Powers of Ten) - http://www.wordwizz.com/pwrsof10.htm
2. Website of Eames video - http://powersof10.com
3. Another web version - http://micro.magnet.fsu.edu/primer/java/scienceopticsu/powersof10/
4. Another web version - http://microcosm.web.cern.ch/Microcosm/P10/english/P0.html
5. Data and Powers of Ten - http://www2.sims.berkeley.edu/research/projects/how-much-info/datapowers.html